(12) UK Patent Application (19) GB (11) 2 376 362 (13) A

(43) Date of A Publication 11.12.2002

(21) Application No 0113791.8

(22) Date of Filing 06.06.2001

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(51) INT CL^7
H03H 9/25

(52) UK CL (Edition T)
H3U UAB UC U22

(56) Documents Cited
GB 2035005 A
EP 0957576 A2
WO 1998/027647 A1
JP 090284085 A
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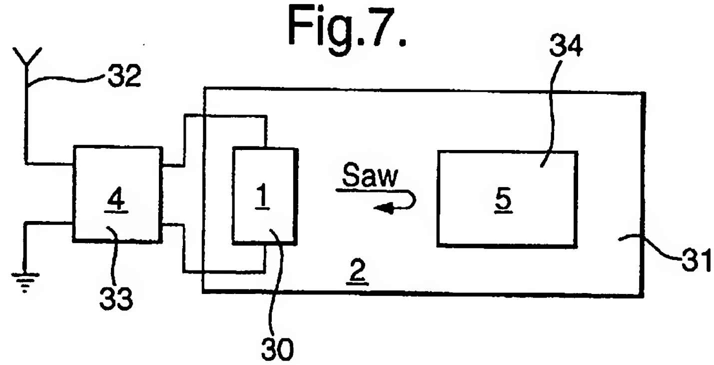
(58) Field of Search
Other: ONLINE: WPI, EPODOC, JAPIO

(54) Abstract Title
Sensor apparatus including unidirectional SAW device and reflector

(57) The apparatus includes a substrate 31 upon which is mounted a Surface Acoustic Wave device 30 and means 34 for reflecting surface acoustic waves transmitted by the substrate 31, wherein the Surface Acoustic Wave device 30 comprises a uni-directional inter-digital transducer. The apparatus has lower insertion losses than prior art devices.

The substrate 31 may carry multiple reflectors (figs 8 and 9).

Fig.7.



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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

The claims were filed later than the filing date but within the period prescribed by Rule 25(1) of the Patents Rules 1995.

Fig.1.

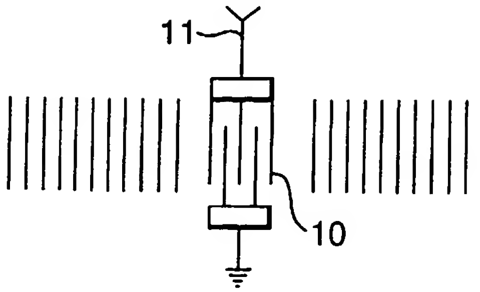

Fig.2.

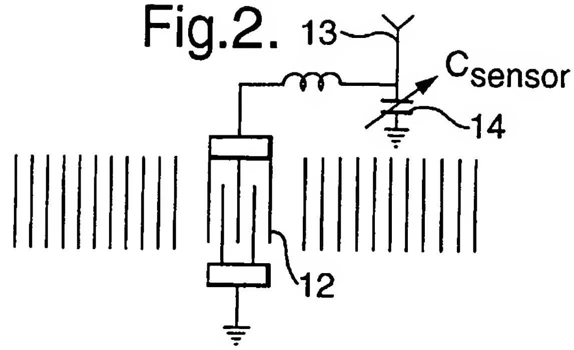

Fig.3.

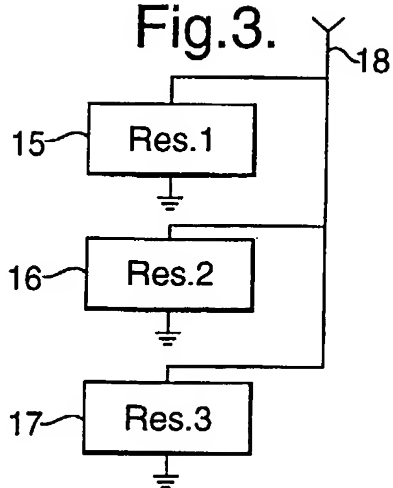

Fig.4A.

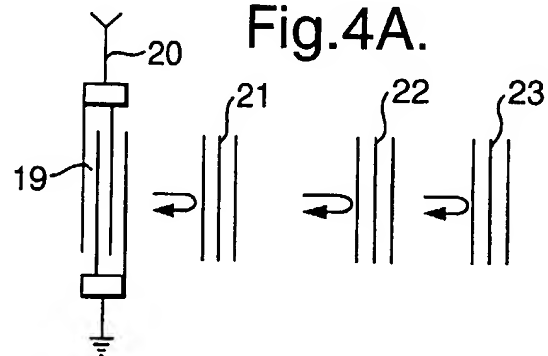

Fig.4B.

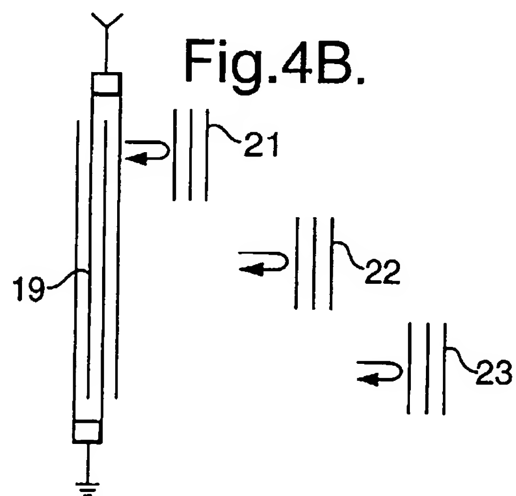

Fig.5.

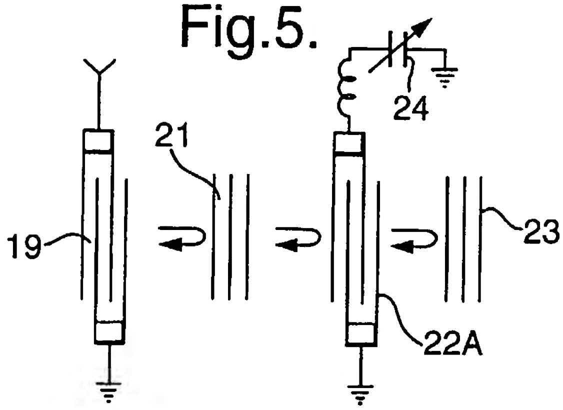

Fig.6A.

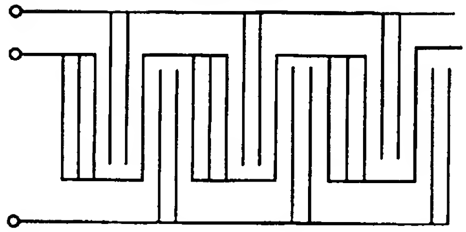

Fig.6B.

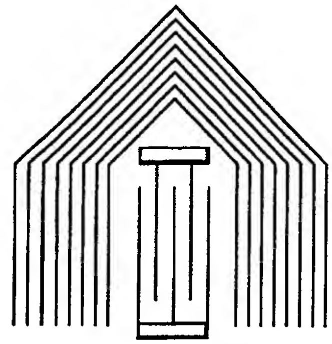

Fig.6C.

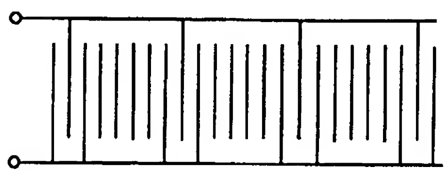

Fig.6D.

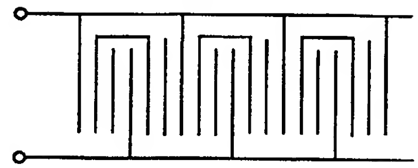

Fig.7.

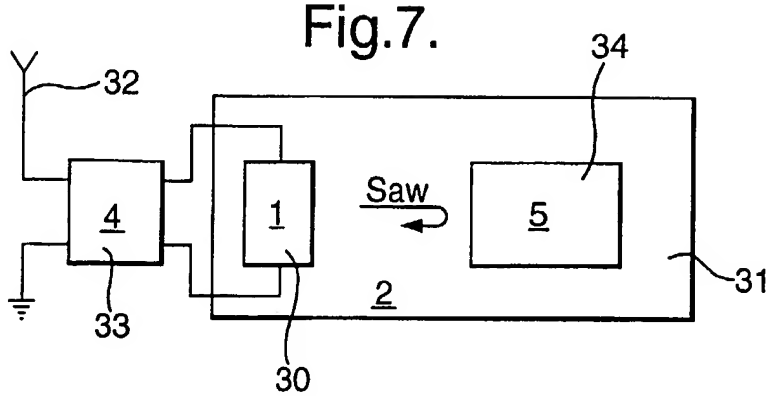

Fig.8.

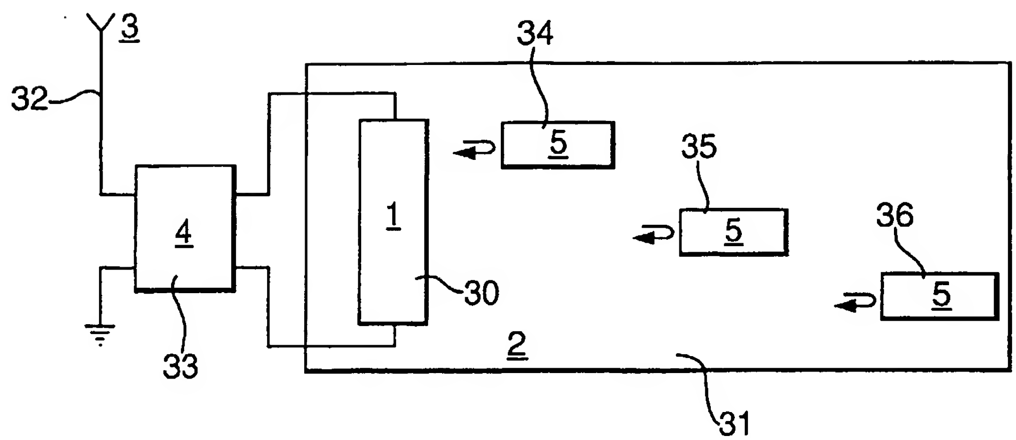
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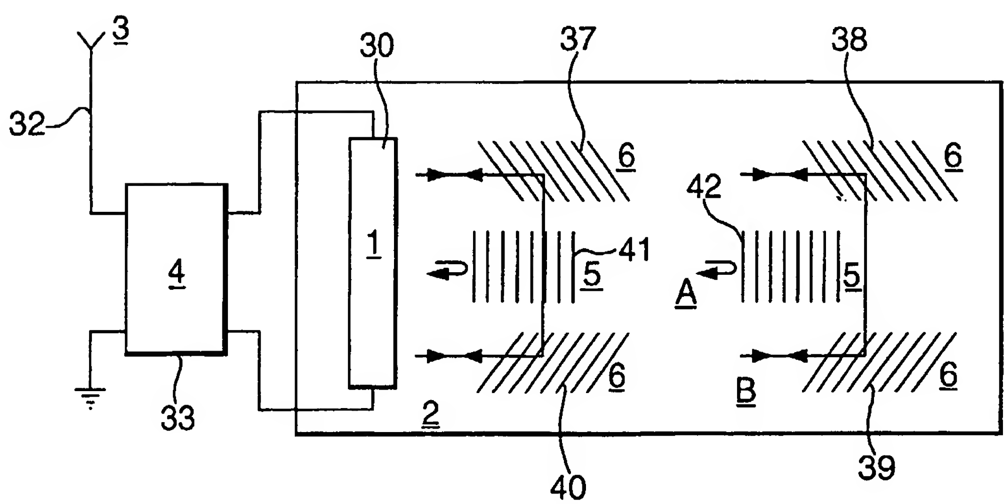
Fig.9.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IMPROVEMENTS IN AND RELATING TO SENSOR SYSTEMS INCORPORATING ACOUSTIC WAVE DEVICES

This invention relates to sensor systems which incorporate surface acoustic wave devices.

It is known in the prior art to use surface acoustic wave (SAW) devices to allow a sensor to be interrogated from a point remote from the sensor. To this end, a drive circuit is provided to send a pulse of RF energy via a suitable non-contact RF link (e.g. an antenna) to the SAW device. The SAW device will, in response to the burst of RF energy, resonate at a resonant frequency characteristic of the condition being sensed, and will re-transmit a pulse of energy (or a group of pulses) to appropriate detection equipment which, again, is not physically connected to the SAW device but rather is connected to it by means of some non-contact link. With such arrangements, the SAW device and its associated condition sensor can be physically separated from the drive and detection circuitry. Further, the SAW device and sensor can, with appropriate design, be designed to operate without the need for a dedicated power supply. As a result of these factors the SAW device and sensor may be, for example, secured to a rotating shaft or mounted on or in the tyre of a motor vehicle, and appropriate physical conditions sensed without providing any physical contact between the shaft or tyre and the drive and detection circuitry.

There are various known types of the system outlined above in which the SAW device is used in a number of different ways.

Referring firstly to Figure 1, one prior art arrangement makes use of a one-port SAW resonator 10, which is connected to an antenna 11 either directly or through a matching circuit. The SAW device is chosen such that the natural resonant frequency of the SAW device depends on a condition to be sensed, for example temperature. The RF interrogation signal excites the natural resonant frequency of the SAW device. The resonant frequency is re-transmitted by the antenna 11 and is picked up by

suitable detecting equipment. The detective resonant frequency is a measure of the physical condition being sensed. An alternative arrangement is shown in Figure 2. In this case, the SAW device 12 is connected to an antenna 13 and to a capacitive sensing device 14. The capacitance of the sensing device is dependent on the condition being sensed (for example temperature) and as the capacitance changes the resonant frequency of the SAW device is changed even though the SAW device itself is not sensitive to changes in the condition sensed.

With either of the above systems, several different SAW devices (if appropriate with external sensors) 15,16,17 may be connected to a single antenna 18 (Figure 3) to enable independent or simultaneous measurement of several different physical quantities, for example independent measurement of pressure and temperature.

A significant advantage of the resonator type SAW sensor described above is that a considerable portion of the incident energy supplied to the SAW device by the interrogation signal is re-transmitted as a response signal. This means that the devices can operate over a relatively long distance and are relatively insensitive to noise. There is, however, a significant disadvantage in that individual sensors can only be distinguished from each other by their respective resonant frequency bands. In other words, any particular SAW sensor will have an inherent resonant frequency band required to operate. To an extent, the band can be chosen at will with the result that a number of sensors can be produced having different operating frequency bands. Because of the different operating frequency bands the sensors can be distinguished from each other. However, the available number of frequency bands is usually limited and for this reason it is difficult to implement systems which incorporate many sensors.

An alternative arrangement is to use the SAW device as part of a delay line with one or more bi-directional inter-digital transducers (IDTs) and one or more reflecting gratings. Such an arrangement is shown in Figure 4. The SAW device 19 is again connected to an antenna 20 by a suitable means. The SAW device 19 is a bi-directional IDT. The SAW device is laid down on a substrate which also has laid

down on it several reflecting gratings 21,22,23. The gratings may be in line with each other as illustrated in Figure 4a or offset from each other as offset from Figure 4b. The operation of this device relies on the fact that the group or phase delays of the reflected and re-transmitted signals depend on ambient conditions. A modification of this arrangement is shown in Figure 5 where one of the reflecting gratings 22a is itself an IDT loaded by a capacitive sensor 24 which varies the phase of the IDT reflection co-efficient.

An advantage of the SAW delay line sensor is that both time and code division multiplexing can be used to build multi-channel sensor systems. As a result, the required frequency band can be narrower than in the case of the resonator systems described above and the limitations imposed by the need for separate frequency bands for separate sensors are removed. However, the delay line system has the disadvantage that it is subject to high insertion losses, typically in the range of 25-30dB. This reduces the operating system range.

To an extent, the insertion losses are as a result of the nature of the IDT devices used in prior art constructions. Heretofore, the IDT devices used have been bi-directional, that is they have emitted acoustic waves along the substrate material in equal measure from both sides of the device. In the case of a transducer matched to the antenna this results in a loss of at least 6dB. A further source of loss has been the deliberately low reflectivity of the gratings which has been chosen in order to reduce multiple reflections between the gratings and the bi-directional IDT. Typically, less than 10% of the incident power is reflected from the gratings.

The object of the present invention is to produce a delay line SAW sensor which retains the ability of time and code division multiplexing associated with prior art devices, and yet which has lower insertion losses than devices of the prior art. It is a further object of the present invention to provide a SAW delay line sensor which avoids generating parasitic signals due to multiple reflections between the transducer and the gratings.

The invention will be better understood from the following description of a

preferred embodiment thereof, reference being had to the accompanying drawings wherein:

Figures 1-5 illustrate the SAW sensors of the prior art; and

Figures 6-9 illustrate the SAW devices in accordance with the present invention.

In accordance with the present invention, the insertion losses inherent in prior art devices are reduced by using uni-directional transducers (UDt) instead of the bi-directional IDTs of the prior art. In addition, the reflectors are made of high reflectivity. The UDt can be of any type, for example a multiphase UDt as shown in Figure 6a, a UDt with a 3dB multi-strip coupler as shown in Figure 6b, a single-phase uni-directional transducer (SPUDt) as shown in Figure 6c or a floating-electrode uni-directional transducer (SEUDt) as illustrated in Figure 6d.

A preferred embodiment of the invention is illustrated schematically in Figure 7. The UDt 30 is formed on a substrate 31 of a piezo-electric material and is connected to an antenna 32 by an optional matching network 33. The sensor also includes a reflector 34 which is laid down on the piezo-electric material 31. The reflector 34 may be of any convenient form, for example a reflection grating, an IDt with a suitable load, for example a reactive load, or a multistrip mirror. The reflector 31 has a high reflectivity, for example a power reflectivity of at least 90%. Such a reflectivity can be obtained, for instance, in a grating containing 120 short-circuited aluminium strips or 25 gold strips on YZ-$LiNiO_3$ substrate if the film thickness is 1% of the SAW wavelength. The UDt 30 may be of any uni-directional type, and for example may be of any of the types illustrated in Figure 6.

In use, interrogation signals from a suitable source are picked up by the antenna 32 and applied to the input of the UDt 30. The UDt generates an acoustic signal which propagates in one direction only, that is towards the reflector 34. The high reflectivity reflector 34 reflects a high proportion of the energy incident on it back towards the UDt to be picked up by the UDt and re-radiated by the antenna 32. The combination of the uni-directional UDt and high reflectivity reflector means that a

high proportion of the energy picked up by the antenna 32 is re-radiated after a time delay. The time delay is determined by the distance of the UDt 30 to the reflector 34 and provides an indication of an ambient condition to which the sensor is sensitive. Little or no parasitic signals are generated due to multiple reflections despite the high reflectivity of the reflector because the matched UDt does not reflect acoustic waves incident upon it.

Time and code division multiplexing can be implemented by positioning one or several reflectors in parallel acoustic channels at various distances from the UDt as illustrated in Figure 8. Multi-reflected configurations of the sensor shown in Figure 8 can also be used for differential measurement of the group or phased delays of the signals reflected from the different reflectors.

Figure 9 illustrates a further embodiment of the invention in which inclined reflective gratings 37-40 are used in combination with straight gratings 41,42 to allow simultaneous independent measurement of two physical quantities (for instance temperature and pressure) by one SAW device. Each group of inclined reflectors and its associated straight reflectors provides two path lengths for signals emitted from and back to the UDt. In the case of the group comprising inclined gratings 38 and 39 and straight grating 42 the path lengths are identified by the letters A and B. The delays along paths A and B depend in a different way on temperature and strain due to anisotropy of the piezo-electric substrate. Accordingly, measuring the path lengths gives independent equations for determining temperature and strain. Details of the physical structures referred to above and their method of construction may be had from the following references.

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CLAIMS:

1. Apparatus comprising a substrate upon which is mounted a Surface Acoustic Wave device and means for reflecting surface acoustic waves transmitted by the substrate, wherein the Surface Acoustic Wave device comprises a uni-diectional inter-digital transducer.

2. Apparatus as claimed in claim 1, wherein the reflecting means reflects at least 90% of incident surface acoustic waves.

3. Apparatus as claimed in claim 1 or 2, wherein the reflecting means comprises a plurality of reflectors located in two or more parallel acoustic channels, the distance between the Surface Acoustic Wave device and the or each reflector of one channel being different to the distance between the Surface Acoustic Wave device and the or each reflector of another channel.

4. Apparatus as claimed in claim 1 or 2, wherein the reflecting means comprises at least two reflectors inclined relative to one another and the Surface Acoustic Wave device so that an incident surface acoustic wave from the Surface Acoustic Wave device is, in use, reflected between the reflectors prior to being reflected back towards the Surface Acoustic Wave device.

5. Apparatus as claimed in claim 4, wherein the reflecting means further comprises one or more reflectors arranged perpendicularly to incident surface acoustic waves generated in use by the Surface Acoustic Wave device so that said incident waves are reflected directly back to the Surface Acoustic Wave device.

6. Apparatus as claimed in any of claims 3 to 5, wherein each reflector comprises a reflection grating.

7. Apparatus as claimed in claim 6, wherein each reflection grating comprises 120 short-circuited aluminium strips having a thickness equal to 1% of the wavelength of the surface acoustic wave to be reflected.

8. Apparatus as claimed in claim 6, wherein each reflection grating comprising 25 gold strips having a thickness equal to 1% of the wavelength of the surface acoustic wave to be reflected.

9. Apparatus as claimed in any preceding claim wherein the substrate is of YZ-$LiNiO_3$.

10. Apparatus as claimed in any preceding claim, wherein the reflecting means comprises a loaded inter-digital transducer.

11. Apparatus as claimed in claim 9, wherein the transducer of the reflecting means is under a reactive load.

12. Apparatus as claimed in any preceding claim, wherein the Surface Acoustic Wave device comprises a multiphase uni-directional transducer; a uni-directional transducer having a 3dB multi-strip coupler; a single-phase uni-directional transducer; or a floating-electrode uni-directional transducer.

Application No: GB 0113791.8
Claims searched: 1 to 12

Examiner: Peter Easterfield
Date of search: 13 May 2002

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:
UK Cl (Ed.T):
Int Cl (Ed.7):
Other: Online: WPI, EPODOC, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB 2035005 A	(CLARION)	1,9,11,12
X	EP 0957576 A2	(FUJITSU) see figs 6 & 7	1,4,6,9,12
X	JP 090284085 A	(MATSUSHITA)	1,12
X	US 5661444 A	(DILL et al)	1,3,4,6,12
X	WO 98/27647 A1	(NORTHERN TELECOM)	1,6,12

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.